How manual wheelchairs are used during everyday mobility

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Why understand mobility device use in everyday environments?

• Clinicians and users
  – Relating a clients use (or anticipated use) relative to others may better inform decisions about which devices to select.

• Manufacturers and Suppliers
  – Better information about how products are used can inform design of their products and compare products within their offerings.

• Payers
  – Any data that relates mobility to health or independence or secondary complications should inform policy. We can and should learn more about use to better distinguish users, and therefore coverage.
How far do people walk?

<table>
<thead>
<tr>
<th>Subject set</th>
<th># subjects</th>
<th>Mean Daily Steps</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>6101</td>
<td>9,448</td>
<td>8,899-9,996</td>
</tr>
<tr>
<td>Men</td>
<td>1325</td>
<td>8,412</td>
<td>7,165-9,661</td>
</tr>
<tr>
<td>Women</td>
<td>2338</td>
<td>8,735</td>
<td>7,821-9,648</td>
</tr>
<tr>
<td>US</td>
<td>2107</td>
<td>7,271</td>
<td>6,123-8,418</td>
</tr>
<tr>
<td>Japan</td>
<td>2783</td>
<td>9,317</td>
<td>8,403-10,231</td>
</tr>
</tbody>
</table>

6-7.5 km/day

## How far & over what duration do Manual Wheelchair Users Wheel

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Daily Distance</th>
<th>Daily Time</th>
<th>Daily Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karmarkar et al.</td>
<td>VA nursing homes</td>
<td>1.5 km</td>
<td>n/a</td>
<td>0.48 m/s</td>
</tr>
<tr>
<td>Levy et al.</td>
<td>Adults</td>
<td>1.45 km</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Tolerico et al.</td>
<td>Athletes</td>
<td>2.5 km</td>
<td>48 min</td>
<td>0.8 m/s</td>
</tr>
<tr>
<td>Cooper et al.</td>
<td>Children</td>
<td>1.6 km</td>
<td>n/a</td>
<td>0.67 m/s</td>
</tr>
<tr>
<td>Oyster et al.</td>
<td>SCI</td>
<td>1.9 km</td>
<td>47 min</td>
<td>0.63 m/s</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>--</td>
<td><strong>1.5 – 2.5 km</strong></td>
<td><strong>47.5 min</strong></td>
<td><strong>0.5 – 0.8 m/s</strong></td>
</tr>
</tbody>
</table>

How far & over what duration do Power Wheelchair Users Wheel

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>Daily Distance</th>
<th>Daily time in motion</th>
<th>Avg Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper et al., 2002</td>
<td>17 VA athletes &amp; community users</td>
<td>2.5 km</td>
<td>n/a</td>
<td>0.42 m/s</td>
</tr>
<tr>
<td>Sonenblum, et al., 2008</td>
<td>25 community users</td>
<td>1.9 km</td>
<td>61 min</td>
<td>0.32 m/s</td>
</tr>
</tbody>
</table>

Mean values: will be important later

Compare wheelchair users to ambulatory cohorts with disabilities
Comparing daily distances of movement

• Able-bodied: 6-7.5 km/day
• Amputees: 2-2.4 km/day
• Cane users: 1-1.3 km/day
• Manual wheelchair users: 1.5-2.5 km/day
• Power wheelchair users: 1.9-2.5 km/day

Can we begin to define “mobility disability” by this discrepancy?
How people move about is different than how far people move
Distance, time moving & bouts of mobility

• Three constructs, 2 are commonly described
• Distance and time are very highly correlated
• Bouts of movement
  – Represent transitions between activities
Methods: Measuring Wheelchair Movement

- A solid-state, triaxial, MEMS-based acceleration sensor with a ±2g range mounted on one wheel
- Sampling rate: 10 Hz

![Wheelchair Movement Diagram]
Characterizing Mobility using **Bouts of Mobility**

- Travel between activities

  - **START**
    - Travel at 0.12 m/s for at least 5 seconds
    - Equates to .27 mph for at least 0.6 m or 2 ft

  - **STOP**
    - Travel less than 0.76 m over 15 seconds
    - Allows for pauses in transitions
Characterizing Manual Mobility

• **Subjects**
  - 28 adults, 22 to 91 (median 35)
  - Multiple diagnoses (SCI = 20)
  - Manual wheelchair used as the primary mobility device

• **Protocol**
  - Data collection period varied between 2 & 16 days per subject

• **Record Summary**
  - 29256 bouts of mobility
  - 296 hours of wheeling
  - 595 km wheeled
  - 342 subject-days
Distance and Duration are highly skewed, whereas velocity is more normally distributed.

**Distance (m)**
- 63% of bouts <= 12.5 m
- 85% of bouts <= 30 m

**Duration (s)**
- 63% of bouts <= 30 secs
- 85% of bouts <= 60 secs

**Speed (m/s)**
- 63% of bouts < 0.5m/s
- 85% of bouts < 0.68m/s

**Bouts of manual wheelchair movement**
## Manual Wheelchair Use

### Daily Activity

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouts per day</td>
<td>90</td>
<td>3</td>
<td>235</td>
</tr>
<tr>
<td>Daily distance</td>
<td>1.6 km</td>
<td>7.1 m</td>
<td>10.5 km</td>
</tr>
<tr>
<td>Daily time moving</td>
<td>54.3 min</td>
<td>30 s</td>
<td>208 min</td>
</tr>
</tbody>
</table>

### Bout Descriptions

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bout duration</td>
<td>21.3 s</td>
<td>5.0 s**</td>
<td>40.3 min</td>
</tr>
<tr>
<td>Bout distance</td>
<td>8.6 m</td>
<td>0.8 m</td>
<td>3.83 km</td>
</tr>
<tr>
<td>Bout speed</td>
<td>0.43 m/s</td>
<td>0.09 m/s</td>
<td>1.9 m/s</td>
</tr>
</tbody>
</table>

≈85% of bouts are shorter than 60 seconds & 30 meters at a rate <0.7 m/s
Let’s look deeper at 2 people

- Female
- 22 years old
- Cerebral palsy
- Employed
- Independent in transfer
- Cannot stand or ambulate

- Male
- 24 years old
- Spina Bifida
- Employed
- Independent in transfer
- Cannot stand or ambulate
• Same mean daily distance over a week
• 2 km is about 35-40% of a typical US ambulating adult
• ♂ shows a typical pattern with depressed weekend activity
• ♀ shows less day to day variance (25% vs 50% C.V.)
• Both full time users in wheelchairs for many hours
• ♂ pretty much in chair while awake
• ♀ appears to transfer into and out of chair (she is employed)

• ♀ more activity while in chair
• Does ↑ activity rate mean ↑ exertion?
• Stunning that a ♂ in his 20’s seems to ‘hang out’ more
Power Wheelchair Movement vs. Manual Wheelchair Movement

### Median Bout Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (m)</td>
<td>8.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Duration (sec)</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Speed (m/s)</td>
<td>0.43</td>
<td>0.25</td>
</tr>
</tbody>
</table>

What factors might explain these differences?
How people walk

Levine, JA, et. al; Diabetes. 2008

- On average, a participant took 47 walks per day
- 85% were <15 min in duration
- 88% occurred at < .9 m/s (2 mph)

Orendurff MS, et. al; JRRD 2008

- 90% of walking bouts <100 steps
- 40% of bouts <= 12 steps
- 3% of bouts lasted >= 3 min

Note the similarity with wheelchair movement: small bouts predominate
Wheeling and Walking

• Similar profiles
• Daily movement is dominated by short bouts

<table>
<thead>
<tr>
<th>Walking (Orendurff )</th>
<th>Manual WC</th>
</tr>
</thead>
<tbody>
<tr>
<td>60% ≤ 30 s</td>
<td>63% ≤ 30 s</td>
</tr>
<tr>
<td>81% ≤ 70 s</td>
<td>85% ≤ 60 s</td>
</tr>
</tbody>
</table>

Conclusion: Manual wheelchair users are typical Americans
But only in how they move, not how much
Findings &
Why Should we care?

• Variation of wheelchair use is great across & within people
  – Complicates ability to represent ‘norms’ parametrically
• Wheelchair users have depressed mobility
  – Construct of ‘mobility disability”
• Short bouts of movement dominate wheelchair usage
  – Wheelchair users move about like ambulators
• Short bouts of mobility are defined by starting, stopping and turning
  – Starting handrim forces are higher than continuation forces
  – Maneuvering needs to be a key functional consideration
• Application of findings can inform research into
  • propulsion efficiency
  • secondary complications of wheelchair use
  • clinical prescription of wheelchairs
The Team

• Sharon Sonenblum, PhD
• Ricardo Lopez, PhD
• Jayme Caspall

The Disclaimer
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